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NACA

RESEARCH MEMORANDUM

SUMMARY OF LOCATIONS, EXTENTS,

AND INTENSITIES OF TURBULENT AREAS ENCOUNTERED DURING

FLIGHT INVESTIGATIONS OF THE JET STREAM FROM

JANUARY 7, 1957 TO APRIL 28, 1957

By Martin R. Copp

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NATIONAL ADVISORY COMMITTEE
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SUMMARY OF LOCATIONS, EXTENTS, AND INTENSITIES OF TURBULENT AREAS ENCOUNTERED DURING FLIGHT INVESTIGATIONS OF THE JET STREAM FROM JANUARY 7, 1957 TO APRIL 28, 1957

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SUMMARY

A summary of the locations, extents, and intensities of turbulent areas encountered during a flight investigation of the jet stream is presented. The data were obtained from NACA VGH time-history records.

INTRODUCTION

A flight investigation of the jet stream utilizing a Boeing B-47 airplane was undertaken by the Air Force Cambridge Research Center (ref. 1). The National Advisory Committee for Aeronautics cooperated in this flight investigation to the extent of providing instruments for measuring the turbulence and the evaluation of the data. A summary of the extents of the turbulent areas and the altitudes and times at which they were encountered is presented in reference 2 for the period October 1953 to July 1955. This report summarizes subsequent data obtained for the period January 1957 to April 1957.

SCOPE OF DATA AND APPARATUS

The flight records covered the period from January 7, 1957 to April 28, 1957. The records from 20 flights were obtained mostly over the central part of the United States with occasional missions flown to the west coast and with some flights over the southeastern part of the country. VGH records were not obtained from flights 10, 11, and 12 because of instrument malfunctions. Flight altitudes for the

separate traverses along or across the jet stream varied from about 23,000 feet to 42,000 feet in an attempt to obtain detailed data on parameters, such as the wind and turbulence field at a given altitude in the jet stream, and also to define the cross section of the jet stream. A more detailed description of the tests is given in reference 1. The data presented herein represent approximately 45,000 miles of flight.

The NACA VGH recorder used to obtain the turbulence measurements is described in reference 3. Basically, the instrument contains two pressure capsules and an accelerometer element to record the time histories of airspeed, altitude, and vertical acceleration. However, for this investigation, the accelerometer element was removed from the VGH recorder and an airspeed cell was installed which permitted reading of airspeed fluctuations down to approximately 2 feet per second at the normal cruising speed of the airplane. The fluctuations in indicated airspeed provided a measure of the longitudinal gust components for use in determining the locations, extents, and intensities of the turbulent areas.

The recorder contained 200 feet of film, and, with the film speed of about 3.7 inches per minute used in the present tests, film was available for approximately $10\frac{1}{2}$ hours of flight. In general, continuous records were taken from the time of take-off to the time of landing. One-minute timing marks were impressed on the VGH records as an aid in locating the turbulent areas encountered and in computing the total distance flown.

EVALUATION AND PRESENTATION OF DATA

In evaluating the VGH records, the turbulent areas were defined by the portions of the records which contained horizontal gust components as measured from the mean flight speed of at least 5 feet per second (true airspeed). This does not infer that, in all portions of a given area of turbulence, gust velocities of at least 5 feet per second were continuously encountered. Large portions of the areas designated as turbulent contained gust velocities of lower magnitude which probably were not discernible to the flight personnel. No correction for the response of the airspeed system of the VGH recorder was made in reading the fluctuations from the records since the detailed lengths and sizes of the tubing used in installing the instrumentation were not known. On the basis of information available on similar airspeed systems, it is estimated that, for the altitude range covered by the present tests, the peak velocity values are accurate to within ±5 percent. It is considered, therefore, that the airspeed readings provided a consistent measure of the horizontal gust intensities for use in defining the turbulent areas.

The locations of the turbulent areas are listed for each flight in table I in terms of the elapsed time from take-off. Also given in table I are the average pressure altitude and the indicated airspeed of the airplane during the time the turbulence was encountered. The extent of each area of turbulence was determined from the time during which the airplane was in the turbulent region and the average true airspeed. As a measure of the turbulence encountered, the number of true gust velocities equal to or greater than 10 feet per second, as well as the maximum true gust velocity for each turbulent area, are also tabulated. The times when cruising altitude was reached and when descent was started are noted in the table for each flight in order to provide a basis for correlating the locations of the turbulent areas with other meteorological measurements taken in the airplane.

DISCUSSION

The turbulence encountered during the investigation was generally light, as in reference 2, and covered approximately 12 percent of the total distance flown. A comparison of the data in table I indicates that the most severe turbulence was encountered during flight 27, on March 29, 1957. During this flight, the table indicates that the true gust velocities ranged up to 37 feet per second as compared to values generally less than 20 feet per second for the remainder of the flights. The extent of the turbulence encountered during flight 27 was approximately 23 percent of the total distance flown. Although larger areas of continuous turbulence were encountered on other flights, for example flight 29, the maximum true gust velocity encountered and the number of gusts per mile of turbulent air were considerably less for these turbulent areas than for the most turbulent areas of flight 27.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., Nov. 20, 1957.

REFERENCES

1. Endlich, R. M., Harney, Patrick, McLean, G. S., Rados, Robert M., Tibbets, O. J., and Widger, W. K., Jr.: Project Jet Stream - The Observation and Analysis of the Detailed Structure of the Atmosphere Near the Tropopause. Bull. Am. Meteorol. Soc., vol. 35, no. 4, Apr. 1954, pp. 143-153.

2. Fetner, Mary W.: Summary of Locations and Extents of Turbulent Areas Encountered During Flight Investigations of the Jet Stream From October 1953 to May 1954 and November 1954 to July 1955. NACA RM L55H04a, 1956.

3. Richardson, Norman R.: NACA VGH Recorder. NACA TN 2265, 1951.

TABLE I.- SUMMARY OF JET-STREAM TURBULENCE DATA

Location of turbulence referenced from take-off		Pressure altitude, ft	Indicated airspeed, mph	Extent of turbulence, miles	Number of true gust velocities ≥10 fps	Maximum true gust velocity, fps	Remarks	
Start	End						Time cruise began, min	Time descent began, min
Time, min	Time, min							
Flight 8; January 7, 1957								
155.0	156.3	42,000	262	12.6	--	7	22.3	253.5
173.4	174.8	42,000	254	13.0	--	7		
Flight 9; January 10, 1957								
68.4	70.0	30,000	328	14.1	--	8	13.5	157.1
99.9	100.5	34,000	284	4.4	--	5		
138.0	139.6	34,000	295	13.6	--	5		
148.2	149.8	34,000	300	14.2	--	7		
Flight 13; January 23, 1957								
98.5	99.1	33,000	330	5.4	--	5	17.3	367.1
99.7	100.1	33,000	320	3.8	--	5		
112.8	116.6	29,000	270	27.8	--	9		
126.5	129.1	24,000	336	21.7	--	6		
131.5	136.0	23,000	358	38.7	3	10		
140.5	144.1	33,000	283	30.1	3	12		
147.8	156.0	35,000	290	70.5	5	15		
158.0	158.3	35,000	294	2.5	--	7		
162.6	163.1	35,000	296	4.4	--	6		
168.2	168.9	35,000	297	6.6	--	5		
175.1	180.1	35,000	297	4.0	2	10		
214.4	215.0	37,000	276	5.6	--	7		
Flight 14; January 24, 1957								
185.1	191.9	36,000	288	60.6	--	6	33.4	406.4
262.2	262.7	36,000	284	4.4	--	5		
279.6	280.0	36,000	282	3.7	--	5		
289.3	291.1	36,000	286	16.0	--	8		
331.2	333.4	36,000	285	18.4	--	7		
Flight 15; January 25, 1957								
63.3	64.1	36,000	304	8.3	--	5	34.8	225.7
74.9	80.1	35,000	310	2.3	--	6		
Flight 16; January 27, 1957								
97.4	100.9	37,000	284	31.3	--	8	17.2	150.1
Flight 17; February 5, 1957								
60.8	61.4	29,000	303	5.5	--	5	22.6	316.6
75.3	76.2	29,000	313	7.7	--	7		
112.6	113.2	36,000	265	5.0	--	6		
227.8	230.4	32,000	298	21.5	1	12		
Flight 18; February 15, 1957								
21.3	23.3	24,000	349	17.1	--	6	10.3	95.5
30.3	32.1	24,000	365	16.1	--	7		
33.7	38.1	24,000	355	37.6	2	11		
51.1	51.5	24,000	351	3.7	--	8		
72.9	74.4	27,000	323	12.6	--	8		
77.2	77.5	28,000	330	3.3	--	7		
82.3	86.4	28,000	334	36.2	2	12		
90.0	92.5	28,000	340	22.3	--	7		
Flight 19; February 16, 1957								
29.9	30.2	34,000	281	3.0	--	7	29.7	305.3
119.0	120.5	28,000	286	11.4	--	8		
193.5	195.2	31,500	298	14.6	--	6		
241.9	242.3	34,000	254	3.2	--	5		
268.1	268.9	35,000	282	7.0	--	6		
281.3	283.8	37,000	277	22.5	--	6		

TABLE I.- SUMMARY OF JET-STREAM TURBULENCE DATA - Continued

Location of turbulence referenced from take-off		Pressure altitude, ft	Indicated airspeed, mph	Extent of turbulence, miles	Number of true gust velocities 510 fps	Maximum true gust velocity, fps	Remarks	
Start	End						Time cruise began, min	Time descent began, min
Time, min	Time, min							
Flight 20; February 20, 1957								
110.0	111.7	33,000	284	14.5	--	7		
116.1	117.0	35,000	277	7.1	--	6		
177.5	183.7	37,000	258	50.4	2	11	25.5	306.2
232.0	234.5	39,000	261	21.5	--	8		
300.5	302.0	41,000	258	13.0	--	6		
Flight 23; March 9, 1957								
28.8	29.4	33,000	399	6.8	1	10		
41.0	41.7	34,000	328	6.8	--	5		
43.9	50.4	34,000	328	62.0	2	10		
54.0	54.9	36,000	330	9.1	--	8	16.1	223.7
62.4	74.7	34,000	328	118.7	50	17		
79.7	80.5	36,000	321	7.6	--	7		
110.3	110.8	35,000	323	4.3	--	5		
213.4	214.4	35,000	329	9.6	--	6		
Flight 24; March 19, 1957								
35.7	36.2	35,000	280	4.4	--	5		
99.6	103.6	35,000	274	32.3	--	8		
112.0	113.8	35,000	284	15.1	--	6		
159.5	160.1	40,000	242	4.7	--	5		
164.1	165.2	41,000	242	9.0	--	5		
167.6	169.0	41,000	246	11.9	--	8		
181.4	184.4	36,000	280	26.0	--	7	21.7	338.9
190.4	192.2	37,000	283	6.6	--	5		
211.6	213.1	38,000	262	12.7	--	8		
225.4	229.3	37,000	272	33.5	--	7		
240.4	252.4	37,000	268	101.1	6	13		
260.3	260.5	35,000	308	1.9	--	6		
297.0	297.6	35,000	292	5.3	--	8		
Flight 27; March 29, 1957								
80.7	90.2	35,000	284	81.0	74	32		
92.9	95.7	36,000	287	23.9	26	16		
103.2	115.2	36,000	274	100.7	--	8		
121.1	123.4	36,000	280	19.5	6	16		
127.9	131.2	36,000	280	28.2	1	11		
132.8	143.4	35,000	292	103.7	85	35		
157.1	157.6	36,000	278	4.3	3	16		
158.9	168.1	35,000	292	80.5	82	37		
171.4	176.6	36,000	290	46.2	--	5		
180.6	183.3	36,000	290	24.3	--	8		
185.0	187.8	35,000	289	24.7	--	8		
190.6	194.2	35,000	286	30.7	--	5		
194.9	197.5	37,000	280	23.5	--	8		
199.3	200.2	37,000	273	8.1	--	6		
206.8	210.9	37,000	269	34.9	--	8	22.5	419.2
217.8	217.9	37,000	271	.9	--	6		
219.0	228.8	37,000	270	83.1	23	17		
235.7	235.9	37,000	267	1.9	--	6		
242.3	243.2	39,000	270	8.0	--	6		
250.8	251.3	39,000	270	4.6	--	9		
252.7	254.6	39,000	271	16.6	8	12		
255.6	256.2	39,000	272	5.1	--	9		
258.5	259.2	39,000	269	5.8	--	9		
259.9	261.3	39,000	269	11.7	--	9		
261.8	263.2	39,000	265	12.4	--	9		
264.3	265.1	39,000	266	6.6	--	9		
290.9	291.1	41,000	267	2.6	--	9		
339.7	340.8	41,000	250	9.6	--	9		
356.8	356.9	41,000	250	.7	1	15		

TABLE I.- SUMMARY OF JET-STREAM TURBULENCE DATA - Continued

Location of turbulence referenced from take-off		Pressure altitude, ft	Indicated airspeed, mph	Extent of turbulence, miles	Number of true gust velocities 5:0 fps	Maximum true gust velocity, fps	Remarks	
Start	End						Time cruise began, min	Time descent began, min
Time, min	Time, min							
Flight 28; April 1, 1957								
30.4	32.5	34,000	306	18.9	7	15	20.6	340.0
35.7	43.9	34,000	308	74.3	27	19		
46.0	48.2	34,000	308	19.7	--	6		
57.3	57.9	34,000	303	5.3	--	7		
67.4	82.2	34,000	296	128.7	14	13		
118.2	123.8	36,000	296	50.7	--	8		
122.8	139.0	38,000	280	91.2	24	15		
141.7	146.5	38,000	280	43.7	3	11		
152.8	153.6	38,000	282	7.8	--	6		
158.8	159.5	36,000	292	6.7	--	6		
163.3	165.8	36,000	298	22.5	--	5		
170.9	174.1	36,000	300	29.3	--	7		
175.1	178.4	36,000	296	34.2	--	8		
179.7	198.6	36,000	292	169.4	7	13		
206.5	208.2	36,000	297	15.6	1	10		
219.7	222.2	36,000	298	22.8	3	10		
298.6	301.2	39,000	270	22.8	--	7		
316.8	317.5	40,000	269	7.1	--	9		
324.1	330.9	40,000	277	64.0	--	7		
336.0	340.0	42,000	264	37.1	3	12		
Flight 29; April 4, 1957								
146.5	148.1	36,000	288	13.1	1	26	22.6	294.7
201.3	202.1	37,000	275	7.5	--	5		
213.3	213.9	38,000	274	5.6	--	5		
229.8	230.6	39,000	270	7.4	8	18		
253.1	272.7	40,000	264	352.4	62	26		
279.5	281.7	40,000	261	18.7	--	5		
Flight 30; April 8, 1957								
37.5	67.5	35,000	310	277.9	5	11	30.5	226.5
105.9	107.0	33,000	324	10.3	--	6		
110.9	114.2	36,000	296	30.1	--	7		
117.5	120.5	36,000	292	27.2	1	10		
142.2	144.3	36,000	292	18.6	--	6		
149.0	149.7	38,000	282	6.2	1	10		
153.8	164.4	38,000	285	96.9	3	11		
186.5	188.6	38,000	288	19.5	--	6		
Flight 31; April 12, 1957								
101.9	109.0	31,000	336	66.4	--	8	26.8	Complete flight not obtained
129.5	131.2	30,000	328	15.1	--	5		
143.8	152.3	30,000	330	76.6	--	7		
159.3	159.9	33,000	315	4.7	--	7		
162.3	163.5	33,000	300	10.1	--	8		
169.5	178.6	33,000	309	81.2	36	15		
346.1	347.6	34,000	300	13.0	--	8		

TABLE I.- SUMMARY OF JET-STREAM TURBULENCE DATA - Concluded

Location of turbulence referenced from take-off		Pressure altitude, ft	Indicated airspeed, mph	Extent of turbulence, miles	Number of true gust velocities, ≥10 fps	Maximum true gust velocity, fps	Remarks	
Start	End						Time cruise began, min	Time descent began, min
Time, min	Time, min							
Flight 32; April 23, 1957								
87.5	89.6	34,000	315	19.4	--	7		
90.6	94.5	34,000	318	36.4	--	6		
95.3	96.9	34,000	322	15.6	--	5		
127.9	145.0	37,000	295	157.3	--	7		
149.0	149.8	37,000	298	7.7	--	5		
163.5	175.1	37,000	290	104.4	40	22	27.4	253.1
181.8	189.2	38,000	290	69.4	41	20		
199.0	200.5	39,000	287	13.4	--	5		
208.5	210.1	39,000	290	15.7	--	5		
211.1	211.5	39,000	287	4.0	--	5		
268.1	268.7	39,000	285	6.1	--	6		
270.6	273.2	39,000	289	24.6	--	7		
300.2	307.9	40,000	285	73.4	--	8		
328.9	334.0	40,000	280	58.0	--	8		
347.6	349.0	40,000	282	13.7	--	5		
Flight 33; April 26, 1957								
26.3	27.9	27,000	370	15.7	--	5		
42.6	46.1	27,000	370	34.0	--	6		
77.2	79.3	28,000	340	18.4	3	11		
83.5	85.8	28,000	330	19.7	--	5		
95.7	99.3	29,000	345	33.2	1	10		
116.1	117.7	31,000	328	14.1	1	10	12.2	320.7
122.2	136.7	31,000	320	128.8	3	12		
149.5	151.3	33,500	310	16.8	--	7		
170.3	173.3	33,000	320	27.5	--	6		
230.3	231.5	32,500	333	11.3	--	5		
236.6	239.3	32,000	335	24.8	--	5		
250.6	251.0	33,000	317	3.2	--	7		
295.3	297.1	38,000	290	17.0	--	5		
Flight 34; April 28, 1957								
37.7	47.9	35,000	310	94.4	1	13		
50.0	55.3	34,000	311	48.7	2	11		
56.5	60.6	34,000	299	36.6	2	11		
62.0	67.5	34,000	295	47.2	--	9	20.9	236.4
73.1	75.5	34,000	300	20.7	--	6		
80.8	84.6	37,500	233	27.9	--	6		
85.3	85.8	38,000	230	3.6	--	5		
87.1	88.5	38,000	235	11.2	--	5		
92.1	102.9	38,000	233	81.0	--	8		